



## Assessing the Use of Cassava and Potato Ashes as Concrete Admixture

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### KEY WORDS

Cassava peel ash (CPA)  
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### ABSTRACT

Concrete is the most widely used construction material. This research investigated the potential of cassava peel ash (CPA) and potato peel ash (PPA) as supplementary cementitious materials (SCMs) for sustainable concrete production. Agricultural wastes were calcined (CPA at 246 °C for 180 min, PPA at 450 °C for 275 min), ground, and sieved to 45 µm. Chemical and mineralogical analyses (XRF, XRD) showed CPA contained 52.48% SiO<sub>2</sub>, 19.65% Al<sub>2</sub>O<sub>3</sub>, and 7.12% Fe<sub>2</sub>O<sub>3</sub>, while PPA contained 49.82% SiO<sub>2</sub>, 18.93% Al<sub>2</sub>O<sub>3</sub>, and 6.97% Fe<sub>2</sub>O<sub>3</sub>. The combined oxides exceeded ASTM C618's 70% requirement, confirming pozzolanic suitability. Concrete mixes with 0%, 5%, 10%, and 15% replacement levels were tested for slump, density, compressive strength, and water absorption up to 28 days. Results showed strength decreased with higher replacements but remained satisfactory at 5%: CPA and PPA (18.2 MPa) compared to 23.2 MPa for control. Density values ranged 2370–2435 kg/m<sup>3</sup>, while water absorption stayed below 5% at low levels, indicating good durability. Economically, CPA (₦1,500/kg) offered better performance, while PPA (₦1,000/kg) proved more cost-effective for non-structural use. The study concludes that ≤5% CPA or PPA replacement is optimal, promoting sustainable construction while reducing cement usage and agricultural waste.

### 3. INTRODUCTION

Concrete is the most widely used construction material, yet its dependence on cement makes it costly and environmentally unsustainable due to high CO<sub>2</sub> emissions. To address these challenges, research has focused on supplementary cementitious materials (SCMs) that can partially replace cement. Cassava and potato peels, commonly discarded as agricultural waste, are abundant in regions like Nigeria. When calcined, they yield ashes containing reactive oxides with potential pozzolanic properties. Their use in concrete offers both waste management and sustainability benefits. This study examines cassava peel ash (CPA) and potato peel ash (PPA) as partial cement replacements. It evaluates their properties, effects on concrete workability and strength, and cost implications, with the aim of identifying optimal replacement levels for sustainable construction.

The chapter reviews concrete quality factors, hydration mechanisms, and the role of admixtures in enhancing workability, strength, and durability. Admixtures are classified by function (e.g., water reducers, retarders, air-entrainers, corrosion inhibitors). Chemical admixture like plasticizers and superplasticizers improve workability and reduce water

demand. Previous studies on cassava peel ash (CPA) show it can partially replace cement without major losses in workability or strength, especially at low percentages. Potato peel ash (PPA) has also demonstrated positive mechanical and durability effects when optimally blended. Research findings indicate optimal replacement levels often lie between 3% and 15%, with excessive amounts reducing strength and workability.

Analytical techniques like X-ray Diffraction (XRD) and X-ray Fluorescence (XRF) are discussed for assessing mineral composition and pozzolanic potential. CPA generally has higher reactive silica and lower carbon content than PPA, making it slightly more favorable without further treatment. The literature highlights that well-processed agro-waste ashes can serve as supplementary cementitious materials, but performance depends heavily on chemical composition, calcination temperature, and replacement ratio.

## 2. MATERIALS AND METHODS

Cement was used as binding material for concrete casting in this study. From the array of different types of cement, ordinary Portland cement (OPC) will be used which conforms to the requirements of BS EN 196-5:1996. It is said to be the general purpose cement for common use. However it is not prescribed to be used if the concrete is in contact with soil or ground water. River sand used for this study was obtained from river in Lagos. The coarse aggregate was obtained from crushed granite from a quarry site at Lagos Ibadan. The cassava peel ashes were incinerated in an oven at 100oC per minute up to 700°C and were maintained at this temperature for 6 hours to produce the ashes. The cassava and potato peel ash (CPA) will be sieved and large particles retained on the 600µm sieve were discarded while those passing the sieve were used for the study. The water used was a pipe-borne water and free from contaminants collected from a tap in Lagos State.

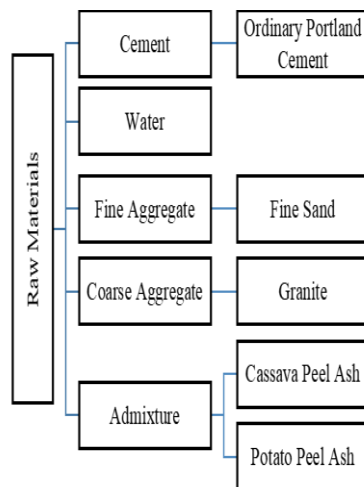


Figure 1: Materials Used in this research

### 2.1 Materials and Equipment

#### 2.1.1 Physical Properties Test

The physical properties of aggregates, ashes, and concrete were determined through standard laboratory tests to evaluate suitability for mix design and performance. Tests were conducted on both fresh and hardened concrete, as well as on cassava and potato peel ashes. Properties assessed included particle size distribution, moisture content, bulk density, specific gravity, water absorption, and compressive strength. Moisture content was determined as the amount of water retained in the sand after air drying, following ASTM D2216. Bulk density and water absorption, which indicate the compactness and pore structure of aggregates, were performed according to ASTM C29 and ASTM D2216-10, while specific gravity was determined using ASTM D854-00. Particle size distribution of

fine aggregate was assessed through sieve analysis in accordance with BS 812-103 (1985). An 800 g sample of sand was passed through a stack of BS sieves (4.75 mm to 0.15 mm). The retained material on each sieve was weighed, and values for percentage retained, percentage passing, and cumulative retention were computed. From these results, the fineness modulus, coefficient of curvature, and coefficient of uniformity were determined to classify the grading of the sand. All tests were performed in compliance with ASTM and BS standards to ensure reliability of results. The particle size distribution and specific gravity test were carried out according to ASTM D422-63.

Calculations:

$$\text{Percentage retained on any sieve} = (\text{weight of soil retained}) / (\text{total weight of sample}) \times 100\% \quad (1)$$

$$\begin{aligned} \text{Cumulative percentage retained on any sieve} &= \text{sum of percentage retained on all sieve} \\ \text{Percentage passing on each sieve} &= (\text{weight of total sample} - \text{weight of retained}) / (\text{total weight sample}) \times 100\% \quad (2) \end{aligned}$$

$$\text{Coefficient of Curvature (CC)} = (D_{30}^2) / (D_{60} \times D_{10}) \quad (3)$$

$$\text{Coefficient of Uniformity (CU)} = D_{60} / D_{10} \quad (4)$$

### 2.1.2 Chemical Composition

X-ray fluorescence (XRF) and X-ray diffraction (XRD) analyses were carried out to determine the chemical and mineralogical properties of cassava peel ash (CPA) and potato peel ash (PPA). The peels were washed, oven-dried and calcined in a muffle furnace at 450°C for 275mins to remove organic matter and convert minerals into oxide forms. The resulting ashes were ground, sieved (75 µm), and prepared for testing. XRF analysis quantified major oxides, including SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub>, CaO, MgO, K<sub>2</sub>O, and Na<sub>2</sub>O, which were compared with ASTM C618 standards for natural pozzolans. XRD analysis was performed with Cu-Kα radiation (λ = 1.5406 Å) to identify crystalline phases. The diffractograms revealed quartz and other crystalline oxides, while broad peaks around 20°–30° 2θ indicated amorphous silica, which is desirable for pozzolanic reactivity. Crystallite size was estimated using the Scherrer equation. These combined analyses provided critical information on oxide composition, crystallinity, and pozzolanic potential of CPA and PPA, consistent with procedures reported in literature (Adesina & Olubajo, 2020; Iqbal et al., 2019).

## 3. RESULTS AND DISCUSSION

### 3.1 Temperature-Time Curve for Cassava Ash

Cassava peels burnt for 180 minutes reached 246°C, passing through drying (~168°C at 60 min), partial combustion (~187°C at 90 min), and complete burnout at 246°C, producing grayish-white ash mainly of SiO<sub>2</sub>, K<sub>2</sub>O, and CaO. The low calcination temperature favored crystalline over amorphous silica, which contributes to pozzolanic reactivity. Figure 2: Temperature–time curve of cassava peel ash. Studies show that higher temperatures (500–700°C) improve amorphous silica content and performance of agro-waste ashes (ASTM C618; Adesina et al., 2020; Olutoge et al., 2012; Oti & Kinuthia, 2014).

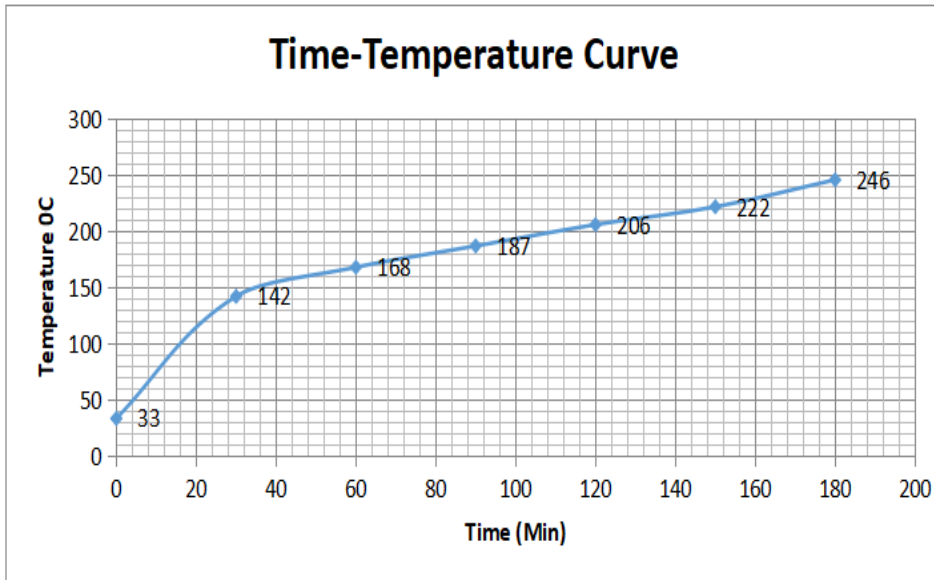


Figure 2: Graph of Temperature against Time (Cassava Peel Ash)

### 3.2 Temperature- Time Curve of Potato Ash

Potato peels burnt for 275 minutes up to 450°C (Figure 3) showed three stages: drying (~168°C), partial decomposition (~187–340°C), and complete combustion at 450°C, producing a light gray, mineral-rich ash. Although stable, the low calcination temperature favored crystalline over amorphous silica, which increases the pozzolanic reactivity.

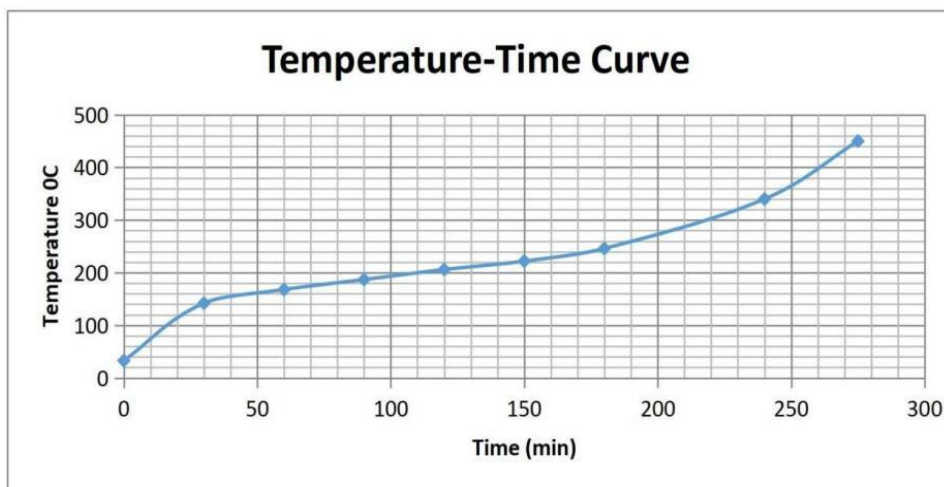


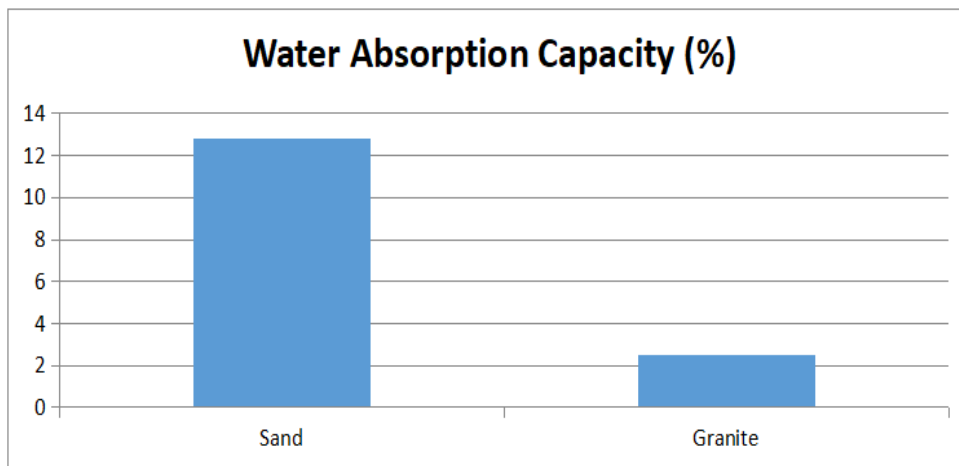
Figure 5: Graph of Temperature against Time (Potato Peel Ash)

### 3.3 Physical properties of Materials

#### 3.3.1 Water Absorption Capacity Result

Aggregate Samples were cleaned and washed before usage to remove any deleterious material. Water absorption indicates aggregate porosity, which affects workability, strength, and durability of concrete. In this study, sand showed 12.83% absorption, while granite recorded 2.5%. Based on BS EN 12620:2013 and ASTM specifications ( $\leq 3\%$  for fine aggregates and 2–3% for coarse aggregates), granite meets the requirement, confirming its suitability. However, the sand greatly exceeds the limit, suggesting high porosity and possible impurities that could reduce effective water for hydration, weaken the concrete matrix, and increase shrinkage risk. Similar findings by Olutoge et al. (2012) and Neville (2011) confirm that fine aggregates with absorption above 10% negatively impact strength

and durability. Corrective measures such as washing, replacement, or mix design adjustments are therefore necessary when using this sand in structural concrete.

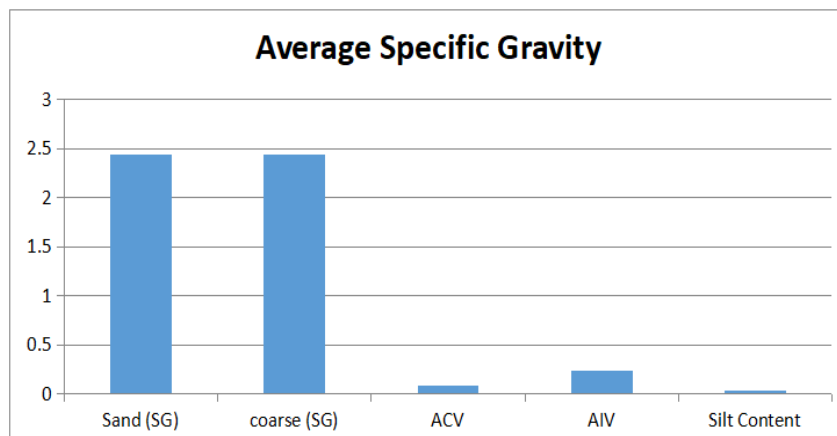


**Figure 3: Average Water Absorption Capacity of Sand and Granite**

Figure 3: Average water absorption capacity of sand and granite, showing granite within standard limits (2.5%) and sand far above recommended values (12.83%).

### 3.3.2 Physical properties of Materials

Both sand and granite recorded a specific gravity of 2.44, within the ASTM C127 and BS EN 1097-6 range (2.4–2.9) but slightly below the ideal 2.6–2.8 for dense concrete. Granite performed well with AIV (24.41%) and ACV (8.54%) below the BS 812 limit of 30%, confirming good resistance to impact and crushing (Oyekan & Kamiyo, 2008; 2011). Sand, however, showed a silt content of 4%, exceeding the BS 882:1992 limit of 3%, which may reduce strength and durability unless washed or replaced.

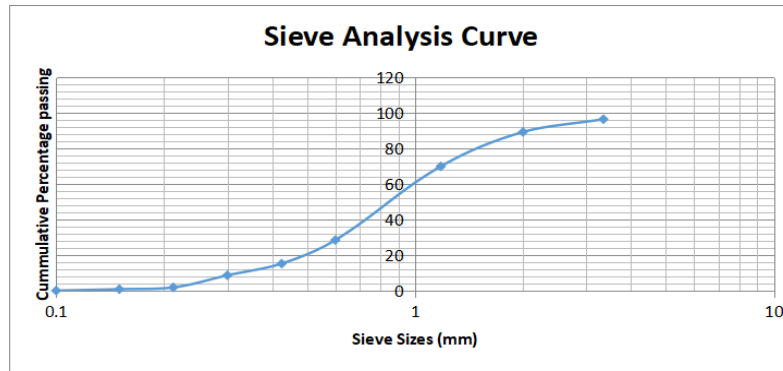


**Figure 4: Average Specific Gravity of Sand and Granite**

Figure 4 is the specific gravity (2.44) of sand and granite, with granite meeting quality standards and sand requiring silt reduction.

### 3.3.3 Sieve Analysis Result

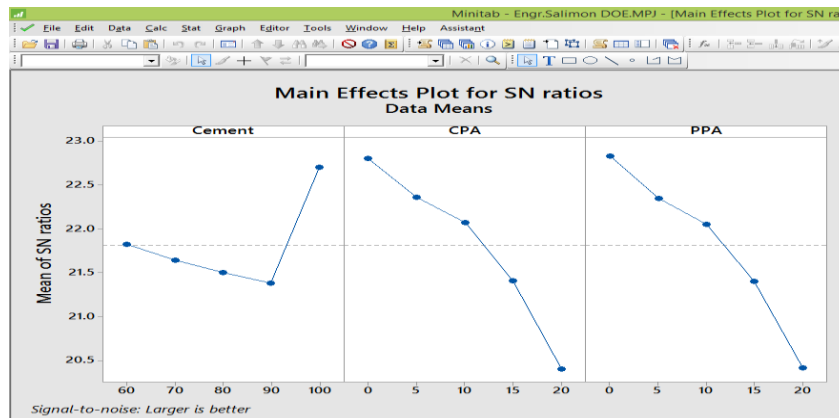
Figure 5 presents the sieve analysis of sand, showing it to be predominantly medium to fine-grained, with most particles between 0.6 mm and 1.18 mm.



**Figure 5: Particle Size Distribution**

### 3.4 Optimization of the Materials using Minitab (Taguchi method)

The Taguchi method (Figure 6) was used to optimize cement replacement with cassava peel ash (CPA) and potato peel ash (PPA) at 0–20%. The optimal blend was 90% cement, 5% CPA, and 5% PPA. This mix achieved balanced strength, durability, and workability, with S/N ratio analysis confirming stable performance under varying curing and environmental conditions.



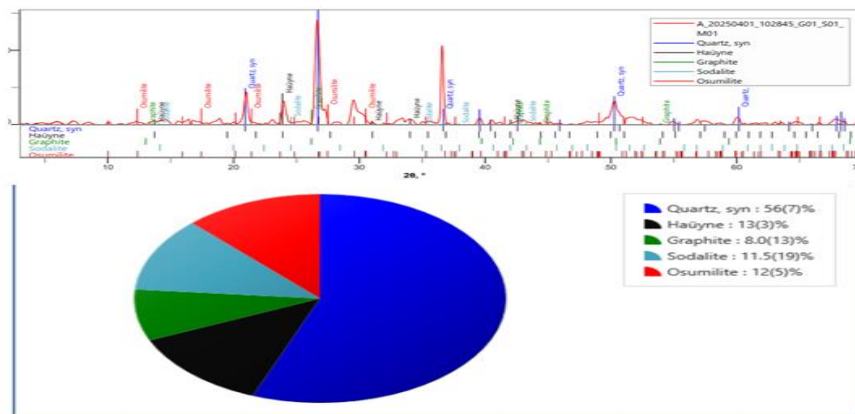
**Figure 6: Materials Optimization**

The Taguchi DOE identified this blend as cost-effective and sustainable, supporting waste valorization, CO<sub>2</sub> reduction, and greener construction practices.

### 3.5 Chemical Composition of Materials

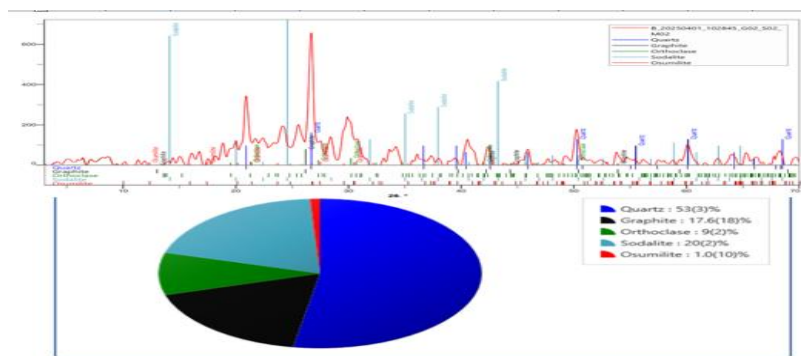
#### 3.5.1 X-Ray Fluorescence (XRF) result

The performance of pozzolanic materials depends on oxide composition, particularly SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, and Fe<sub>2</sub>O<sub>3</sub>, which react with Ca(OH)<sub>2</sub> from cement hydration to form additional C–S–H gel. In this study, the mineralogical composition of cassava peel ash (CPA) and potato peel ash (PPA) was assessed.



**Figure 7: Oxide Composition of Cassava Ash**

Figure 7: Oxide composition of CPA shows quartz (56%) as the dominant phase, indicating high silica but limited reactivity due to crystallinity. Other phases include hauyine, sodalite, and osumilite as alumina–silica sources, while graphite (8%) is mostly inert, confirming CPA’s moderate pozzolanic potential (Ettu *et al.*, 2013; Amu *et al.*, 2011).



**Figure 8: Oxide Composition of Potato Ash**

Figure 8 shows oxide composition of PPA also shows quartz as the main phase, but with a much higher graphite content (17.6%), which may hinder hydration and reduce admixture efficiency (ASTM C618; Mehta and Monteiro, 2014). PPA also contains orthoclase and sodalite, which contribute reactive silica and alumina, with sodalite (20%) supporting long-term pozzolanic action. Thus, PPA shows lower short-term reactivity than CPA but retains potential if further calcined or blended.

### 3.5.2 X-Ray Diffraction (XRD) Result for Cassava Peel Ash

The XRD analysis of cassava peel ash (CPA) revealed distinct peaks, confirming crystalline phases. The most intense peak appeared at  $2\theta = 20.99^\circ$  with d-spacing of 4.233 Å, representing 63.13% relative intensity and indicating dominant crystalline silica ( $\text{SiO}_2$ ). Another significant peak was recorded at  $2\theta = 50.24^\circ$  with moderate intensity (25.77%). Table 1 presents the detailed XRD parameters for CPA. The sharp peaks confirm quartz as the primary phase, consistent with Okoye *et al.* (2016). CPA contains both amorphous and crystalline silica, implying limited pozzolanic reactivity compared to fully amorphous silica, but still with potential as a supplementary cementitious material (SCM) when processed.

**Table 1: XRD for Cassava Peel Ash**

Pos. [°2Th.]	Height [cts]	FWHM Left [°2Th.]	d-spacing [Å]	Rel. Int. [%]
20.9883	57.20	0.1574	4.23278	63.13
23.9570	31.98	0.2362	3.71456	35.29
26.5085	85.28	0.1378	3.36253	94.13
26.7737	89.92	0.1181	3.32982	99.26
29.4911	34.43	0.2362	3.02890	38.00
36.5220	90.60	0.1181	2.46033	100.00
50.2351	23.35	0.2362	1.81620	25.77

### 3.5.3 X-Ray Diffraction (XRD) Result for Potato Peel Ash

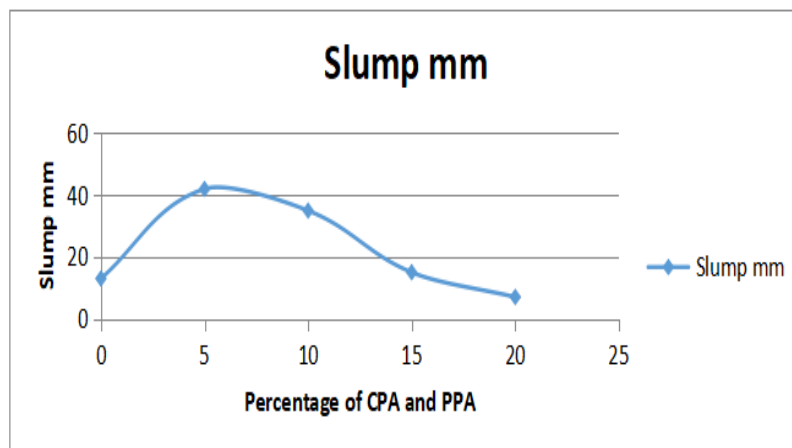
The XRD pattern of potato peel ash (PPA) also revealed crystalline phases. The strongest peak occurred at 26.73° (2θ) with 100% relative intensity, corresponding to quartz (SiO<sub>2</sub>), specifically the (101) plane. A secondary broad peak at 29.73° with 22.92% relative intensity suggests smaller crystallite sizes or amorphous silicate phases. Table 2 summarizes the XRD results for PPA. These findings align with ICDD PDF Card No. 01-089-8936 and studies by *Oyedepo et al. (2014)* and *Daramola et al. (2018)*. The coexistence of sharp quartz peaks and broad amorphous signals confirms that PPA contains reactive silica with good pozzolanic potential.

**Table 2: XRD for Potato Peel Ash**

Pos. [°2Th.]	Height [cts]	FWHM Left [°2Th.]	d-spacing [Å]	Rel. Int. [%]
26.7258	64.29	0.1574	3.33568	100.00
29.9906	14.73	0.9446	2.97958	22.92

### 3.4 Slump Test Result

The slump test revealed clear variations in workability with cassava and potato peel ash replacement. The control sample recorded 13 mm, while 5% replacement achieved the highest slump of 42 mm, showing improved flowability at this level. At 10%, the slump reduced to 35 mm, and at 15% and 20%, values fell sharply to 15 mm and 7 mm. As shown in Figure 9, lower replacement levels enhance workability, but higher contents significantly reduce it, consistent with *Adewumi and Akinwumi (2017)*.

**Figure 9: Slump Test Result**

### 3.5 Average Compressive Strength

The average value of the strength of concrete obtained at 7, 14 and 28 days were shown in Figure 10. The compressive strength results of concrete blended with cassava and potato peel ashes at different replacement levels (0%, 5%, 10%, 15%, and 20%) and cured at 7, 14, and 28 days show a clear trend of strength reduction as the percentage of ash increases. At 7 days, the control sample (0% ash) had the highest strength at 13.3 N/mm<sup>2</sup>, which is expected since it contains full cement content.

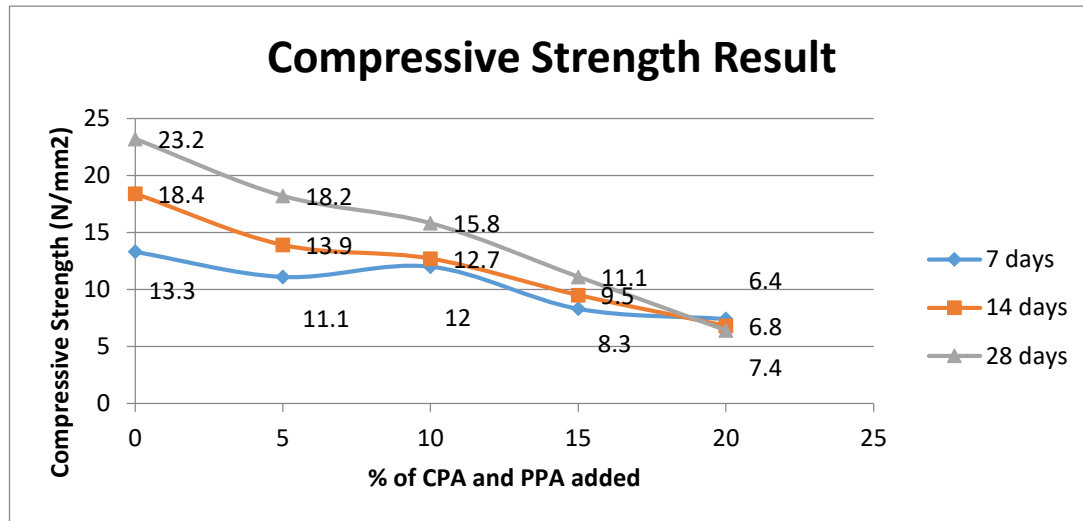


Figure 10: Compressive Strength of Concrete for 7, 14 and 28 Days

At 28 days, which is the standard age for evaluating concrete performance, the control sample reached 23.2 N/mm<sup>2</sup>. The 5% ash mix achieved 18.2 N/mm<sup>2</sup>, which is approximately 78% of the control and meets the ASTM C618 minimum requirement that pozzolanic concrete should reach at least 75% of the strength of the control mix. The 10% mix had 15.8 N/mm<sup>2</sup> (about 68%), indicating marginal compliance. The 15% and 20% mixes performed poorly with 11.1 N/mm<sup>2</sup> and 6.4 N/mm<sup>2</sup>, only 47.8% and 27.6% of the control strength respectively, far below acceptable limits for structural concrete. These results are consistent with findings by other researchers such as *Ogunbode et al. (2017)*, who reported that agricultural ash replacements above 10% generally compromise strength significantly unless optimized with chemical activators or blended with other high-reactivity pozzolans. Furthermore, as noted by Mehta and Monteiro (2014), ashes from agricultural waste often have high silica but low lime content, resulting in slow pozzolanic activity, especially without sufficient curing time or moisture. Therefore, only the 5% ash content satisfies the compressive strength threshold set by ASTM for structural-grade concrete. In addition to standards, the results align with the findings of previous studies by other authors. *Ajamu et al. (2012)* investigated the effect of cassava peel ash (CPA) in concrete and reported that 5% replacement gave the most favorable balance between strength and sustainability, with compressive strength exceeding 75% of the control after 28 days. This agrees with the current findings, where the 5% blend achieved acceptable strength.

They also observed that compressive strength decreased significantly when CPA replacement exceeded 10%, confirming the trend observed in this study. Similarly, *Ogunbode et al. (2017)* studied the use of potato peel ash (PPA) in blended cement and found that strength gain was modest at 5%–10% replacement levels, with 5% showing optimal performance. At higher percentages (15% and above), the dilution of cementitious content and slow pozzolanic reaction of PPA led to substantial strength reduction. This directly supports the performance of the 15% and 20% mixes in the current work, which showed substantial drops in both early and long-term strength. Furthermore, Neville (2011) noted in *Properties of Concrete* that low-lime agricultural ashes often exhibit delayed pozzolanic reactions and may hinder early strength development. The data in this study

reflect that phenomenon, especially at 7 and 14 days, where even the 10% mix struggled to match the control strength.

The decline in strength at 15% and 20% was attributed not only to cement dilution but also to the low binding capacity and delayed reaction of the ash, which is typical of unprocessed agricultural pozzolans. In summary, when comparing with international standards and the outcomes of other research works, the current results confirm that 5% ash replacement with cassava and potato peel ashes is acceptable and meets strength requirements, particularly for normal structural applications. However, 10% may only be suitable for non-structural applications or where longer curing is feasible. Higher replacement levels of 15% and 20% are not recommended due to their failure to meet the strength standards, confirming both international norms and the consensus among researchers. Thus, for practical engineering use, cassava and potato peel ashes should be limited to a maximum of 5–10% replacement of cement, balancing sustainability with structural performance.

### 3.6 Economic Comparison Results

The cost analysis revealed significant variations between cement-only concrete and mixes containing CPPA. At 10% replacement, CPA-based concrete had a total cost of ₦20,280, which is considerably higher than the control mix that cost ₦13,200. On the other hand, PPA-based concrete for the same replacement level cost ₦16,360, which is relatively cheaper than CPA-based mixes but still more expensive than the cement-only mix. The breakdown of these cost comparisons is shown in Table 3, which highlights the differences in material cost due to the use of agro-waste ashes. From the analysis, it can be inferred that CPA may not be cost-effective despite its performance benefits, while PPA shows greater economic viability for non-structural applications.

**Table 3: Cost of Samples Used**

S/N	Sample	Weight used (kg)	Rate	Total (N)
1	Cement	60	220	13200
2	Cassava Peel Ash(5%)	5.6	1500	8400
3	Potato Peel Ash(5%)	5.6	800	4480

## 4. CONCLUSION

Cassava peel ash (CPA) and potato peel ash (PPA) showed potential as supplementary cementitious materials due to their silica and aluminosilicate content. CPA, with higher quartz and lower graphite, performed better than PPA. At 5% replacement, CPA and PPA improved workability and achieved 78% of control strength at 28 days, meeting ASTM C618 standards. However, higher replacements (10–20%) led to poor workability and significant strength loss. Economically, CPA increased cost despite better performance, while PPA was cheaper but gave lower strength, making the combination (CPA and PPA at 5%) more suitable for structural applications.

### Recommendations

#### Recommendations for Sand and Ash Utilization in Concrete Production

1. It is recommended to improve sand grading and blending procedures to minimize voids and enhance particle cohesion, ensuring compliance with relevant standards and maintaining consistent concrete performance.
2. CPA and PPA should be finely ground or calcined to reduce carbon content and crystalline silica levels. The processed ash must achieve a minimum oxide content of 70%, in accordance with ASTM C618, to ensure suitability for use in concrete.
3. The use of CPPA in structural concrete should be limited to a maximum of 5% by weight of cement. For non-structural concrete applications, CPPA may be used up to

10% provided extended curing or appropriate activators are applied to maintain performance.

4. CPA is recommended for structural concrete, while PPA may be employed in cost-sensitive, non-structural works. Local processing methods should be optimized to enhance material efficiency and reduce overall production costs.

## NOMENCLATURE

°C Degree Celcius

## Abbreviations

PPA Potato Peel Ash  
CPA Cassava Peel Ash  
XRD X-Ray Diffraction

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## REFERENCES

- Adesina, A., & Olubajo, O. (2020). Pozzolanic potential of agro-waste ashes in sustainable concrete: A review. *Journal of Cleaner Production*, 256, 120362.
- Ajamu, S. O., Ogunbode, E. B., & Olutoge, F. A. (2012). Strength characteristics of concrete made with cassava peel ash as partial replacement for cement. *Journal of Emerging Trends in Engineering and Applied Sciences*, 3(2), 297-301.
- Daramola, O. O., Adewuyi, A. P., & Olafusi, O. S. (2018). Characterization of cassava peel ash for use as pozzolanic material in concrete. *Nigerian Journal of Technology*, 37(3), 694-700.
- Ettu, L. O., Ajoku, C. A., Nwachukwu, K. C., & Awodiji, C. T. G. (2013). Strength variation of OPC-rice husk ash composites with percentage rice husk ash. *International Journal of Applied Science and Technology*, 3(4), 28-33.
- Iqbal, M. F., Liu, Q., Azim, I., Zhu, X., & Yang, J. (2019). Evaluation of agro-industrial wastes as supplementary cementitious materials: A sustainable approach. *Construction and Building Materials*, 218, 111-121.
- Okoye, F. N., Durgaprasad, J., & Singh, N. B. (2016). Effect of silica fume on the mechanical properties of rice husk ash-based geopolymer concrete. *Journal of Materials Science*, 51(4), 2023-2035.
- Oti, J. E., & Kinuthia, J. M. (2014). Stabilised unfired clay bricks for sustainable construction. *Proceedings of the Institution of Civil Engineers - Engineering Sustainability*, 167(3), 123-135.